MASSACHUSETTS COASTAL COMMERCIAL LOBSTER TRAP SAMPLING PROGRAM MAY-NOVEMBER, 1988

Bruce T. Estrella
and
Steven X. Cadrin

COMMONWEALTH OF MASSACHUSETTS
Division of Marine Fisheries
Department of Fisheries, Wildlife and
Environmental Law Enforcement
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ABSTRACT

This is the Massachusetts Division of Marine Fisheries eighth annual assessment of the status of the American lobster resource in Massachusetts coastal waters. During the period of May through November, 1988, ninety-one sampling trips were made aboard commercial lobster vessels. A total of 39,449 lobster were sampled from 15,832 trap hauls. The catch rate of marketable lobster, 0.820 lobster per trap, was 11% higher than the 1987 index, 0.737. The proportion of females ovigerous, 8.8%, was not significantly different from 1987. Fishing mortality and exploitation rates continued the gradually increasing trend. Mean carapace length increased by 0.7 mm in response to the gauge increase. The percentage of culls increased from 17.0% in 1987 to 18.2% in 1988. The percentage of lobster observed dead in traps was <1%, consistent with previous years.

An assessment of the impact of the first of four 1/32" gauge increases indicated that projected short-term losses were not realized due to favorable recruitment. The most reliable scientific information available supports the benefits of and need to continue the five-year gauge increase program.

INTRODUCTION

This is the Massachusetts Division of Marine Fisheries (DMF) eighth annual assessment of the status of the American lobster, *Homarus americanus*, resource in Massachusetts coastal waters. It was accomplished with regular sea-sampling of the commercial lobster fishery. This fishery is the most economically important single-species fishery in Massachusetts coastal waters. Consequently, a long-term coastwide lobster monitoring program yielding biological and catch per unit effort data was devised and initiated in Massachusetts in May, 1981. A sea sampling-survey design was chosen by which both catch per unit effort and biological data could be collected temporally and areally with sufficient precision for stock assessments. The objective was to assess variations in population parameters due to environmental factors, fishing pressure, and regulatory changes.

Data collected during the 1988 coastwide commercial lobster trap sampling program are summarized below. Parameter trends occurring during the 1981-1988 study period are discussed.

STUDY AREA

The study area is primarily defined by the Massachusetts territorial sea, except where lobstering activities of cooperating commercial lobstermen exceeded territorial boundaries (Figure 1). Territorial waters total 5,322 sq km (2,055 sq n mi), of which an estimated 60% is considered major lobster habitat. Six sampling regions, Cape Ann, Beverly-Salem, Boston Harbor, Cape Cod Bay, outer Cape Cod, and Buzzards Bay, were chosen for coverage of the major lobstering regions of the state. For convenience, these regions are depicted in Figure 1 as generalized hatch-marked areas wherein lobster gear sampled may be discontinuously distributed.

SAMPLING PROCEDURE

Sampling of coastal waters was accomplished by monitoring catches during the normal lobstering operations of volunteer commercial lobstermen in each designated region. Multiple lobstering operations were observed to reduce bias from varying degrees of lobstering skill and to enhance areal coverage. Pot-sampling trips were day trips, conducted a minimum of once per month region during the major lobstering season, May-November.

Utilizing portable cassette tape recorders, sea samplers recorded carapace length (to the nearest mm and to the nearest 0.1 mm between 81 and 81.8 mm to establish the minimum legal size of 81.8 mm); sex; and condition, including the degree of shell hardness, culls and other shell damage, external gross pathology, mortality, and presence of extruded ova on females (ovigerous). Catch in number of lobster, number of trap hauls, set-over-days, trap and bait type were also recorded. Trap locations and depths were recorded from LORAN and depth sounder equipment when available on vessels.

ANALYTICAL PROCEDURES

Data were computer coded and keypunched (by DMF and National Marine Fisheries Service personnel) for analysis on the Woods Hole Oceanographic Institution's Digital Equipment Corporation VAX-11/780 computer system. A computer auditing process was used to uncover keypunch and recording errors and statistical analyses were performed with SPSS (Nie 1983) statistical sub-programs.

The Kolmogorov-Smirnov two sample test and Mann-Whitney U/Wilcoxon W tests were used to determine the significance of year to year variation in parameters.

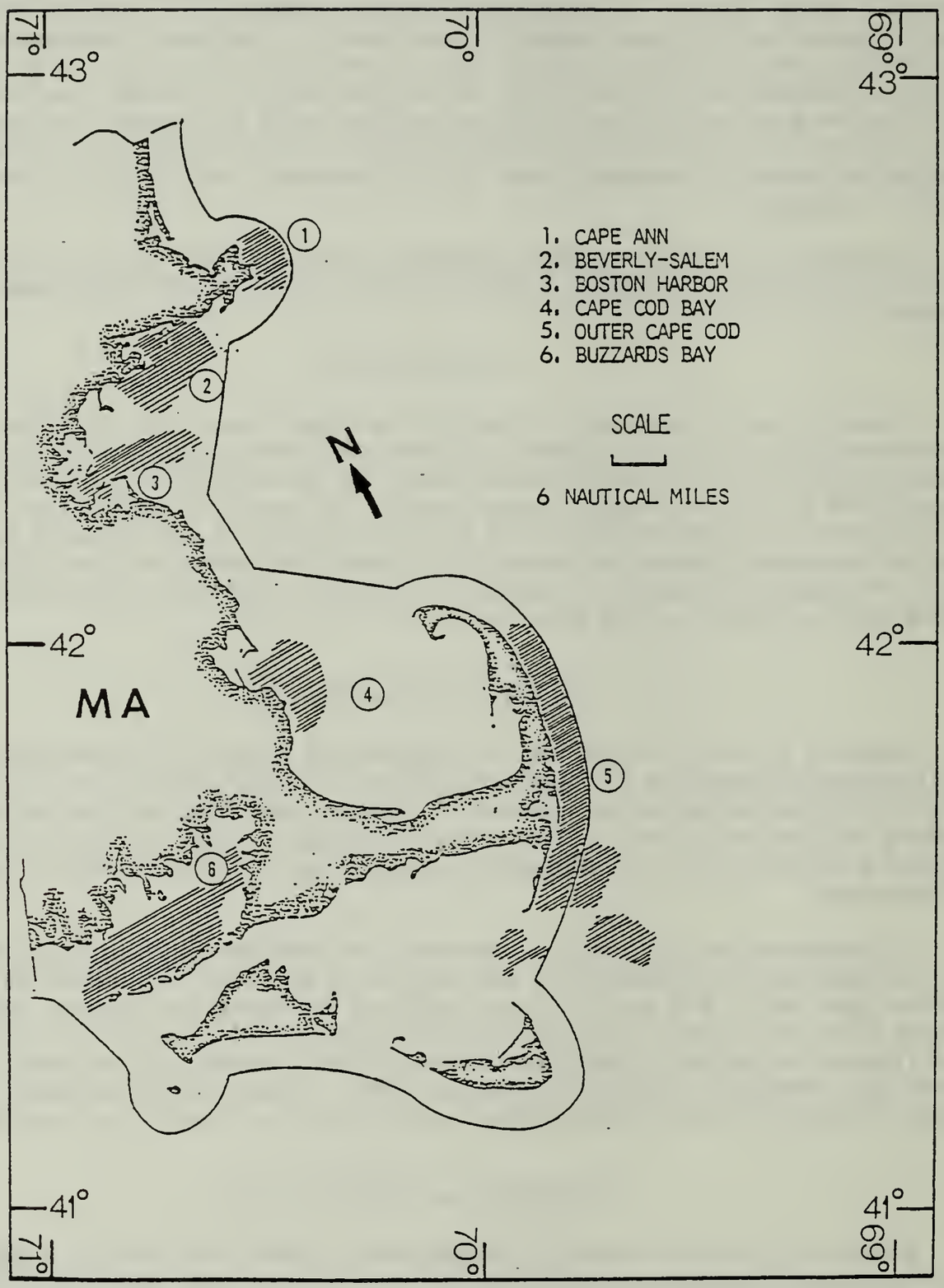

Figure 1. Map of Massachusetts coast with six sampling regions (hatch-marked) and territorial boundary line.

Because parameter means exhibit significant regional and monthly variation, an areal and temporal data weighting scheme was incorporated into analytical software. As a result, each month's data contribute equally to regional parameter means which are weighted by area in square nautical miles to generate coastwide means.

Unless specified otherwise, the terms "legal" or "legal sized" lobster include all lobster in the carapace length category $\geq$ 81.8 mm. The marketable segment of this category, which excludes ovigerous females and, beginning in 1988, also excludes V-notched females, is analyzed separately and referred to as "marketable lobster". The sublegal length category includes all lobster < 81.8 mm.

The catch rates of marketable lobster are expressed as CTH'_3. This is catch per trap haul standardized to the survey mode of 3 set-over-days (Estrella and McKiernan 1987).

Estimates of total instantaneous mortality (Z) and total annual mortality ($A=1-e^{-Z}$) were computed by two methods which produce extremes in the possible range of estimates. The method of Gulland (1969) requires computing the slope of the regression line of numbers at estimated age (15% molt groups, 14% for Buzzards Bay, were derived from tagging data) plotted in the natural log. Beverton and Holt's (1956) process employs von Bertalanffy Growth Equation parameters and mean and minimum length of exploitable sizes.

Estimates of fishing mortality (F) were calculated with Cohort Analysis (Pope 1972). Rates of exploitation were calculated with the equation $u=FA/Z$, where F= fishing mortality, A= total annual mortality, and Z= total instantaneous mortality.

Lobster landings data were derived from lobstermen's catch reports which are compiled annually by the DMF Commercial Fisheries Statistics Project.

Since current management strategy stresses uniform coastwide regulations, all data are grouped for a coastwide analysis. However, the uniqueness of the Massachusetts coastline, its role as a temperature barrier which profoundly affects many marine species (Colton 1964), and the influence of offshore lobster stocks on the inshore resource mandate a regional data treatment as well.

RESULTS AND DISCUSSION

During the period of May through November, 1988, ninety-one sampling trips were made aboard commercial lobster vessels in Massachusetts coastal waters. A total of 39,449 lobster were sampled from 15,832 trap hauls.

The coastwide mean catch rate (CTH'_3), 0.820 marketable lobster per trap, was 11% higher than the 1987 index, 0.737 (Appendix Table 1). Total Massachusetts commercial landings increased by 8% from 1987. Landings from inside 41° N 69° W increased by 7.4%, while landings from territorial waters increased by only 3.5%. Offshore landings increased by 11%. Landings and catch rate trends are depicted in Figure 2. The catch rates of sublegal lobster declined between 1987 and 1988 (Appendix Tables 2 and 3).

Of all females sampled during 1988, 8.8% were ovigerous compared to 9.2% in 1987 (Appendix Table 4). No significant difference was found between years (P = 0.995). Trends in abundance of ovigerous females are depicted in Figure 3 (Appendix Tables 4-6).

Fishing pressure indices increased slightly during 1988 compared to 1987 (Appendix Table 7). Approximately 95% of the legal catch in our inshore regions (Cape Ann south through Cape Cod Bay and Buzzards Bay) was comprised of new recruits, i.e., lobster which were sublegal before their most recent molt. In contrast, this index was lower, 57%, for the primarily offshore migrant lobster east of Cape Cod.

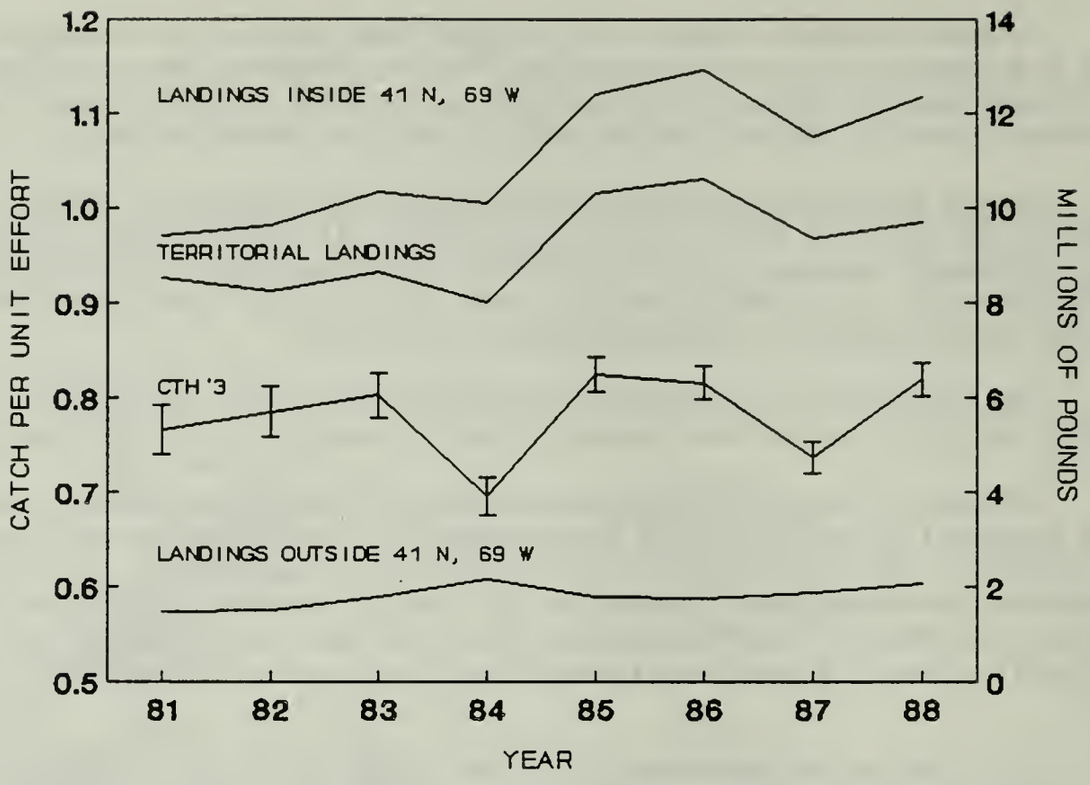

Figure 2. Catch per unit effort from lobster trap sampling and lobster landings from Massachusetts territorial waters, inside 41 °N 69 °W and outside 41 °N 69 °W.

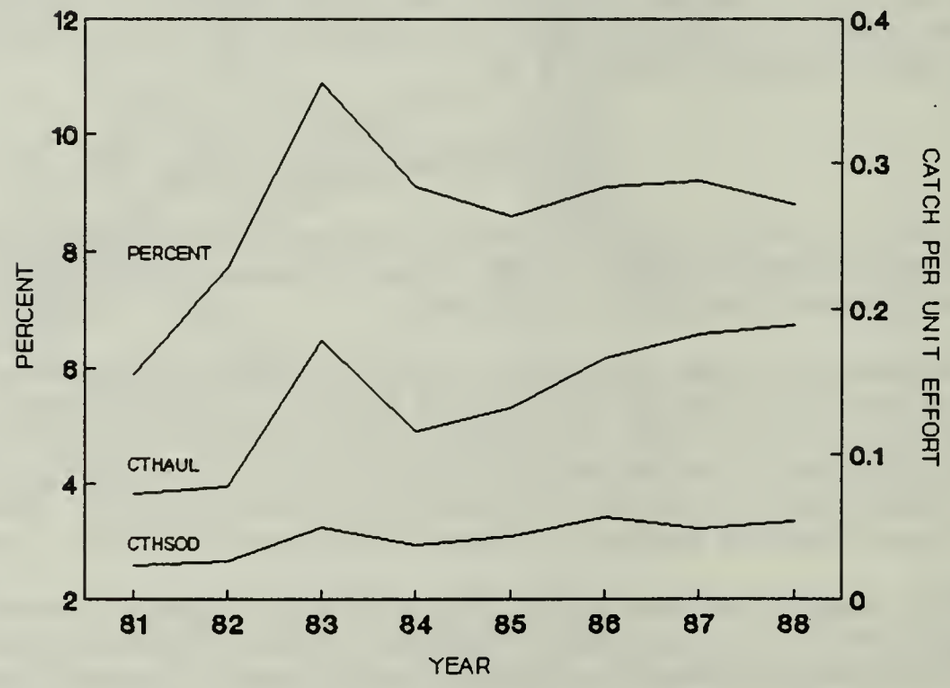

Figure 3. Relative abundance of ovigerous female lobster in percent of total females and catch per unit effort, Massachusetts coastal waters.

Estimates of total mortality (Z) were also high, but they did not change much from 1987. Indices for inshore Gulf of Maine regions (Z = 1.51-3.31, A = 78%-96%) and Buzzards Bay (Z = 2.35-3.18, A = 94%-96%) depict an over-exploited resource while those for the outer Cape Cod region (Z =0.66-0.71, A = 48%-51%) indicate that a lower level of fishing pressure was exerted on this lobster group (Appendix Tables 8a and 8b).

Estimates of instantaneous fishing mortality (F), the proportion of all deaths which are attributed to fishing, ranged from 0.53 off outer Cape Cod to 2.06 in Buzzards Bay (Appendix Table 9). An overall increase occurred during the eight-year study period. A similar trend was observed for the time series of exploitation rates (u), i.e. the fraction of the population that is removed by fishing (Appendix Table 10). Exploitation rates were highest in Massachusetts Bay (Beverly-Salem and Boston Harbor) and Buzzards Bay regions.

The relationship between fishing mortality, rate of exploitation, and mean lobster size is depicted in Figure 4. Carapace length exhibited a downward trend as fishing mortality and exploitation rates increased through 1987. The 0.7 mm increase in mean carapace length between 1987 (87.5 mm) and 1988 (88.2 mm; P < 0.001; Appendix Table 11) may reflect the similar numerical change in the minimum legal size during 1988.

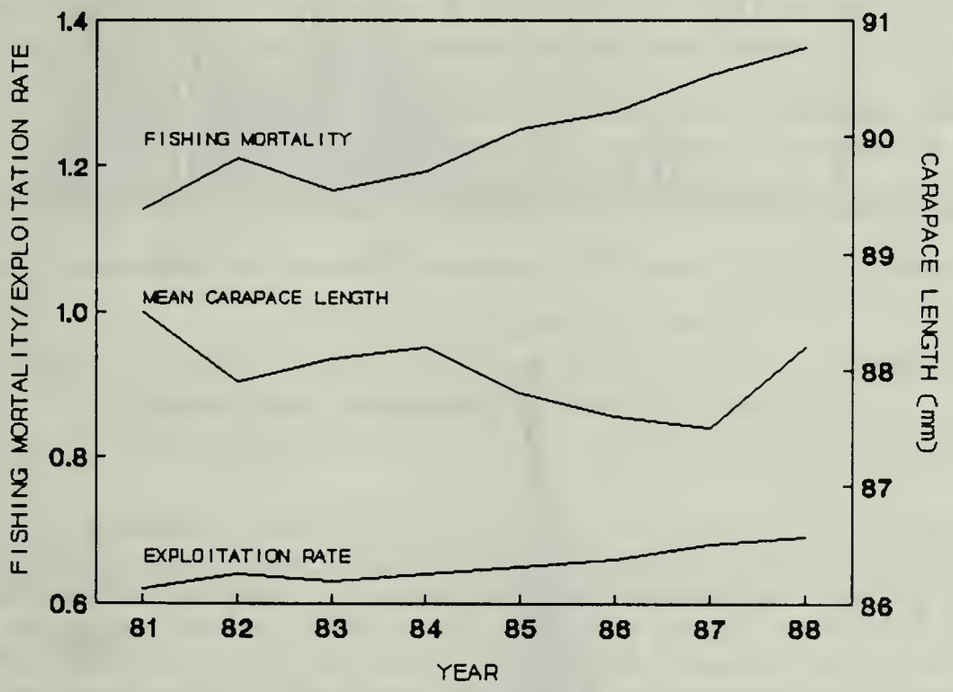

Figure 4. Relationship between exploitation, fishing mortality rates and mean carapace length of lobster, Massachusetts coastal waters, 1981-1988.

Sublegal sized lobster averaged 76.3 mm during 1988 compared to 76.1 mm during 1987 (Appendix Table 12). The mean size of all ovigerous females increased from 87.1 mm in 1987 to 88.2 mm in 1988 (P < 0.001, Appendix Table 13).

The percentage of culls (lobster with one or both claws missing or regenerating) among all lobster sampled increased from 17.0% in 1987 to 18.2% in 1988 (P < 0.001, Appendix Table 14). The cull rates for legal and sublegal size groups increased similarly Appendix Table 15-17).

The coastwide incidence of lobster found dead in traps was < 1%. This was consistent with 1987 data (Appendix Table 18).

Gauge Increase Assessment

On 1 January, 1988 the minimum legal carapace length for American lobster was raised from 81 mm (3 3/16") to 81.8 mm (3 7/32"). This change was promulgated by the New England Fishery Management Council in cooperation with the lobster-producing states in New England and the Mid-Atlantic. The minimum carapace length will be raised by 1/32" (0.79 mm) increments annually over a five year period ending in 1992 with no increase in 1990.

A 7.8% short-term loss in number of lobster, 5.9% loss in weight, was predicted for the Massachusetts inshore fishery during the beginning of the first year of the gauge increase program. This short-term loss was expected to diminish as recruitment from molting adjusted the size frequency.

The CPUE and biological assessment parameters discussed above indicate that the 1988 lobster fishery was not impacted as expected. This was primarily the result of excellent recruitment of sublegal lobster into the legal size range. Size frequency analysis demonstrated that the proportion of sublegal to legal lobster in 1988 (66%/34%) was significantly different from 1987 (71%/29%; Chi-square, $P < 0.0001$). The reduced catch rate of sublegal lobster in 1988 was partly the result of a longer average soak time in that year (4.5116 in 1988 vs 3.8661 in 1987) and a trend toward use of oversized and/or multiple escape vents in some areas (the required escape vent size is scheduled to increase to 1 15/16" in 1992). However, the significant increase in number of legal-sized lobster (11%) indicates that enhanced recruitment was probably largely responsible (Figure 5). The size frequencies of ovigerous females were similar between years (Figure 6).

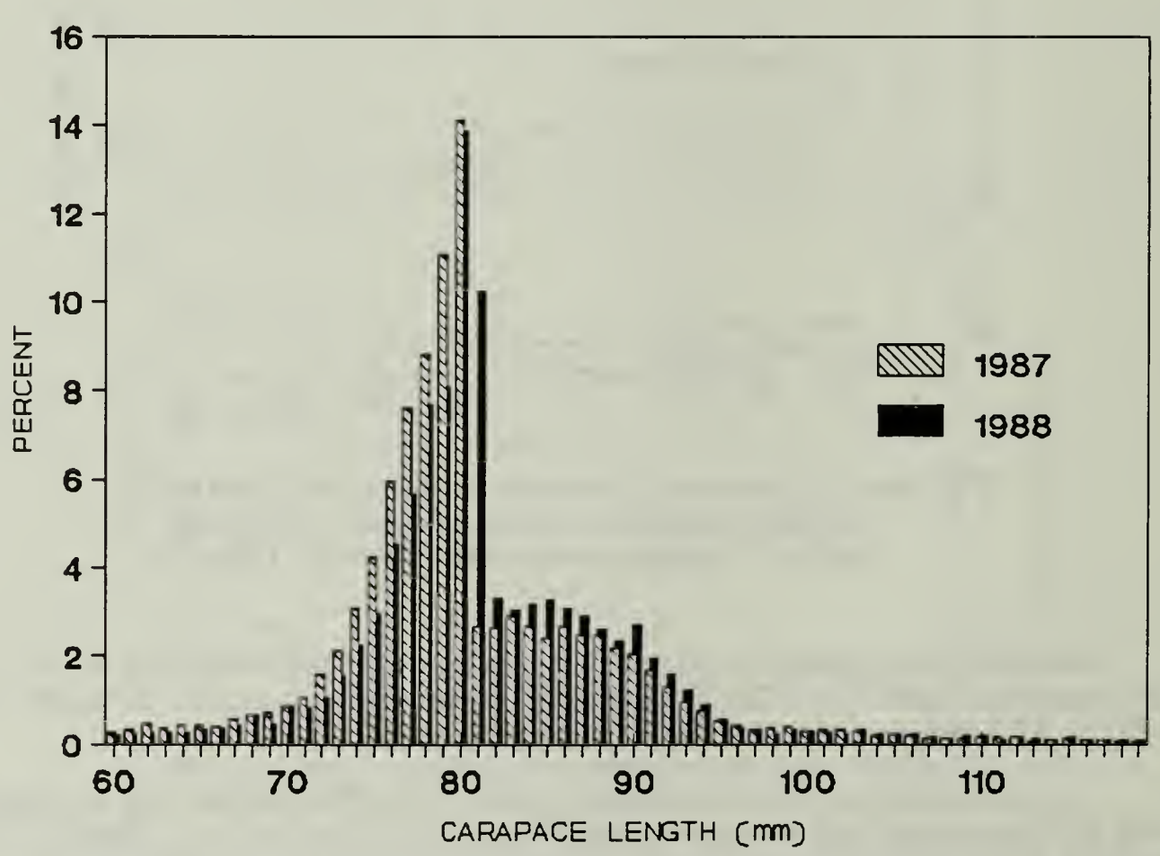

Figure 5. Carapace length frequency of all lobster from commercial lobster trap sampling, Massachusetts coastal waters, 1987 and 1988.

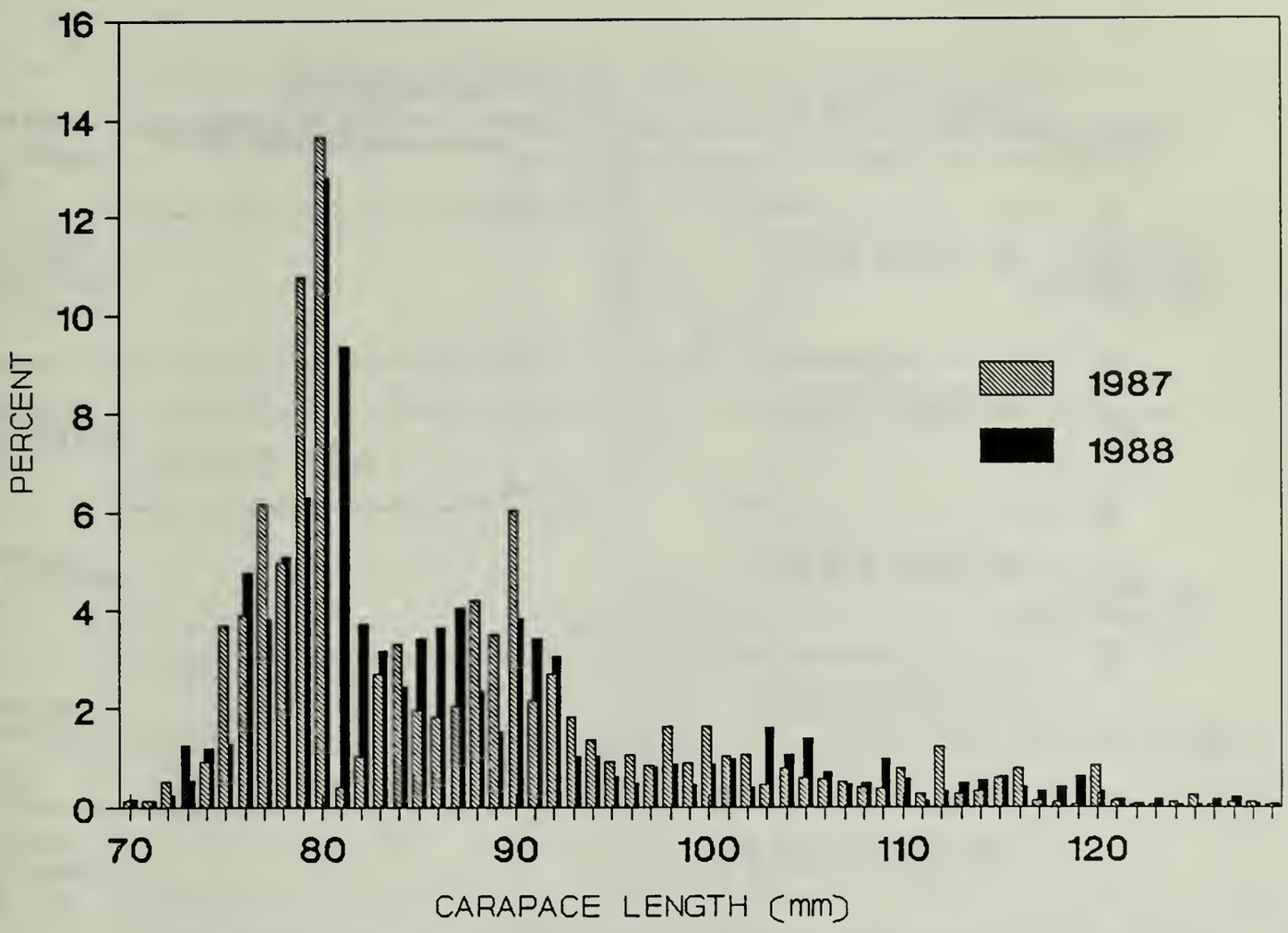

Figure 6. Carapace length frequency of ovigerous female lobster from commercial lobster trap sampling, Massachusetts coastal waters, 1987 and 1988.

There are a number of misconceptions which members of the industry have voiced about the gauge increase program. Questionable hypotheses resulting from preliminary research by a University of Maine scientist have confounded the issue. The contention that an increase in the minimum legal size would result in a greater number of marketable lobster surviving to maturity and migrating beyond the range of the inshore fishery is not supported by any tagging study conducted in inshore environments (Cooper 1970; Fair 1977; Krouse 1977; Fogarty et al. 1980; Campbell 1982; Briggs and Mushacke 1984; Lawton et al. 1984; Landers 1989).

Analysis of 1988 regional length frequency data by 30 ft. depth contours is instructional (Figures 7-12). The relatively small incremental increase from the current minimum size of 82.55 mm C.L. to the proposed minimum size of 84 mm C.L. occurs well below the size at 50% maturity in all regions except Buzzards Bay. A size at functional maturity was not estimated for the Beverly-Salem region; however, it is assumed to be similar to that of Boston Harbor (87 mm C.L.) which exhibits a similar depth and, consequently, temperature range. Despite random variation, very little difference in size structure of commercial catches is evident by depth. This consistency in length frequency occurs regardless of regional differences in the size-at-maturity. The size at 50% female maturity in Buzzards Bay is 76 mm. This is the lowest size-at-maturity of all Massachusetts regions; however, the proportion of sublegal to legal lobster does not vary by depth in this region where the impact of maturity-related migratory behavior should be the greatest. The indications are that any impact of the gauge increase on migratory behavior would be negligible.

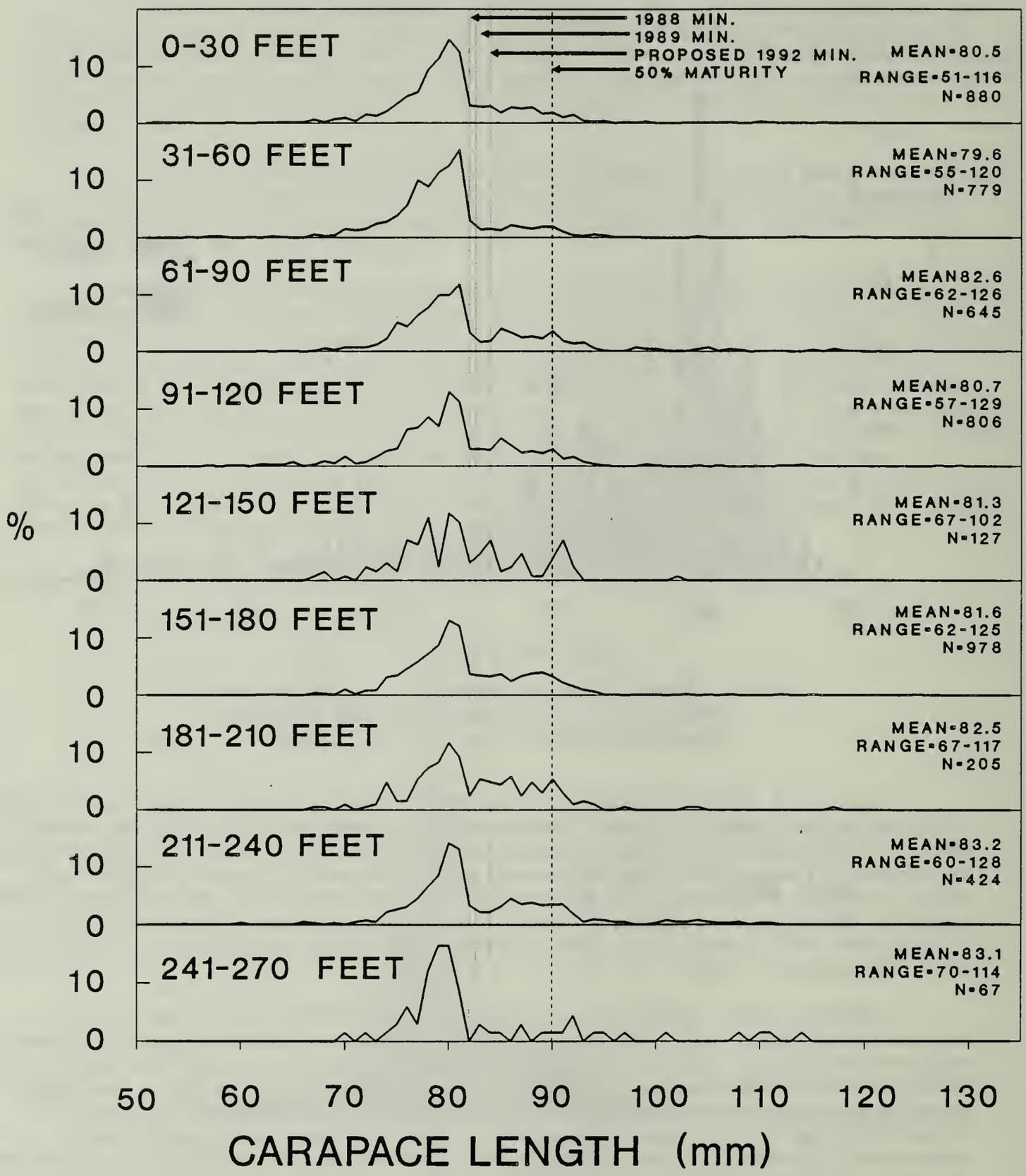

Figure 7. Carapace length frequency of all lobster, by 30 foot depth zones, from commercial lobster trap sampling in Cape Ann region, Massachusetts, 1988.

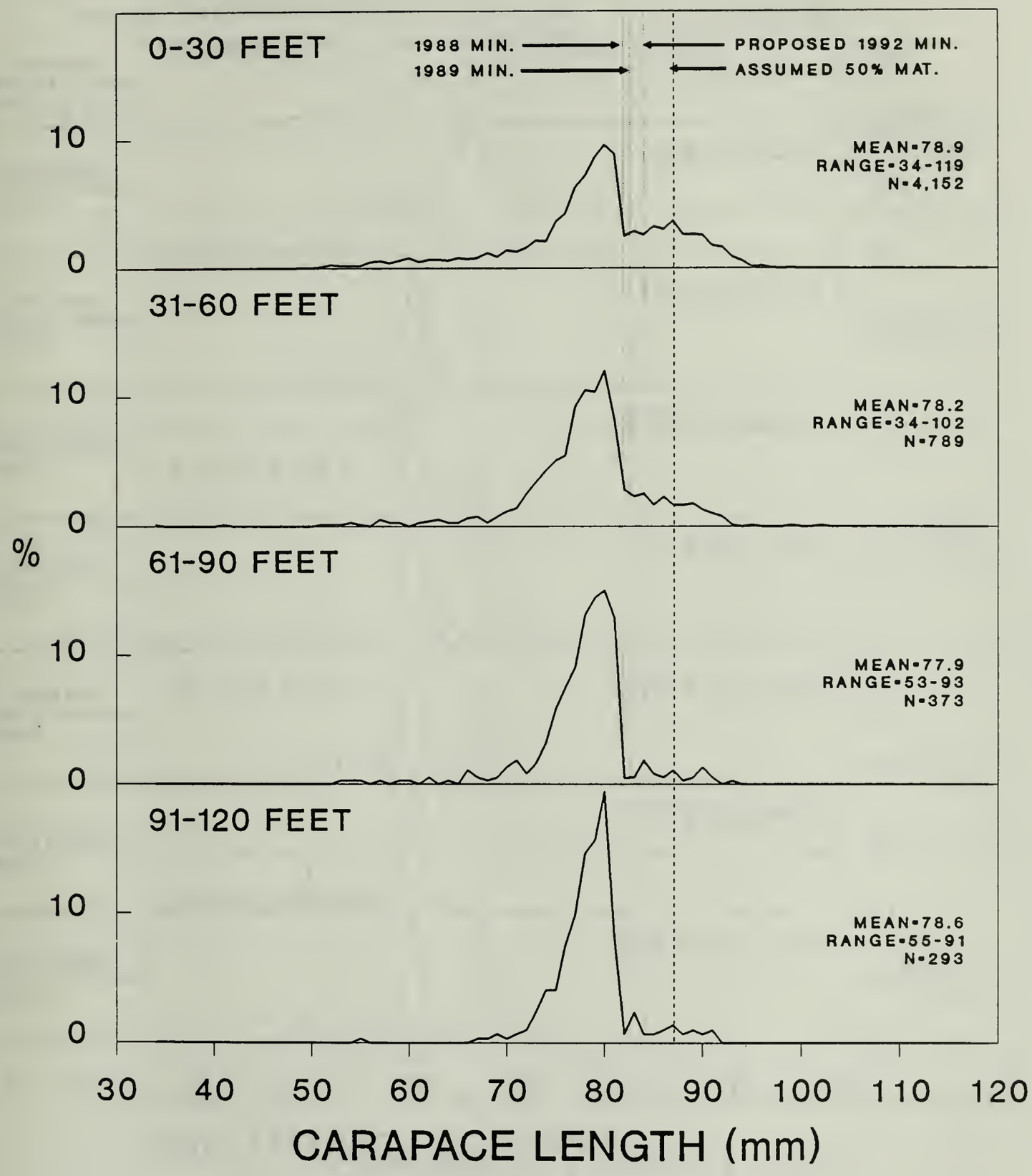

Figure 8. Carapace length frequency of all lobster, by 30 foot depth zones, from commercial lobster trap sampling in Beverly–Salem region, Massachusetts, 1988.

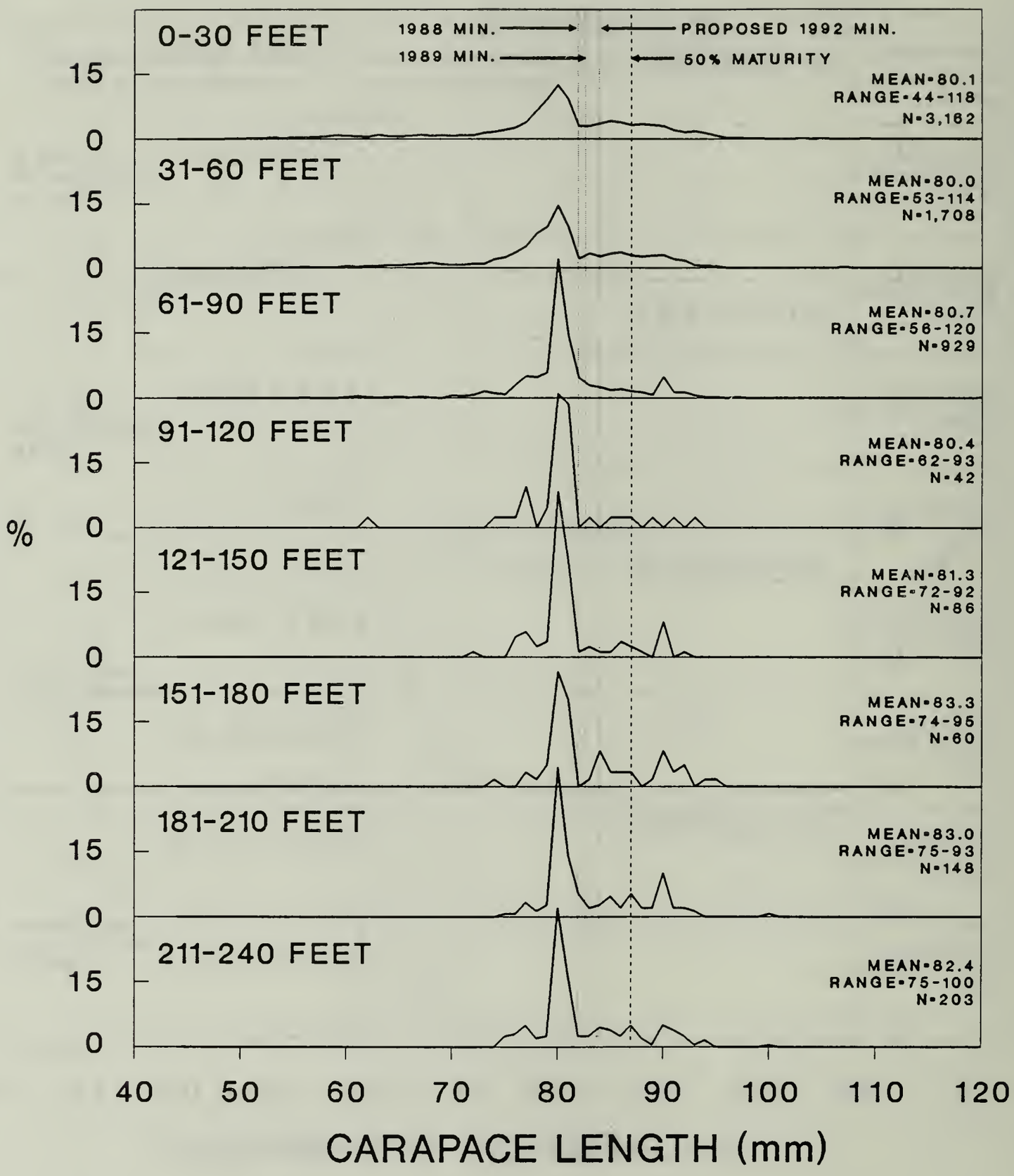

Figure 9. Carapace length frequency of all lobster by 30 foot depth zones, from commercial lobster trap sampling in Boston Harbor region, Massachusetts, 1988.

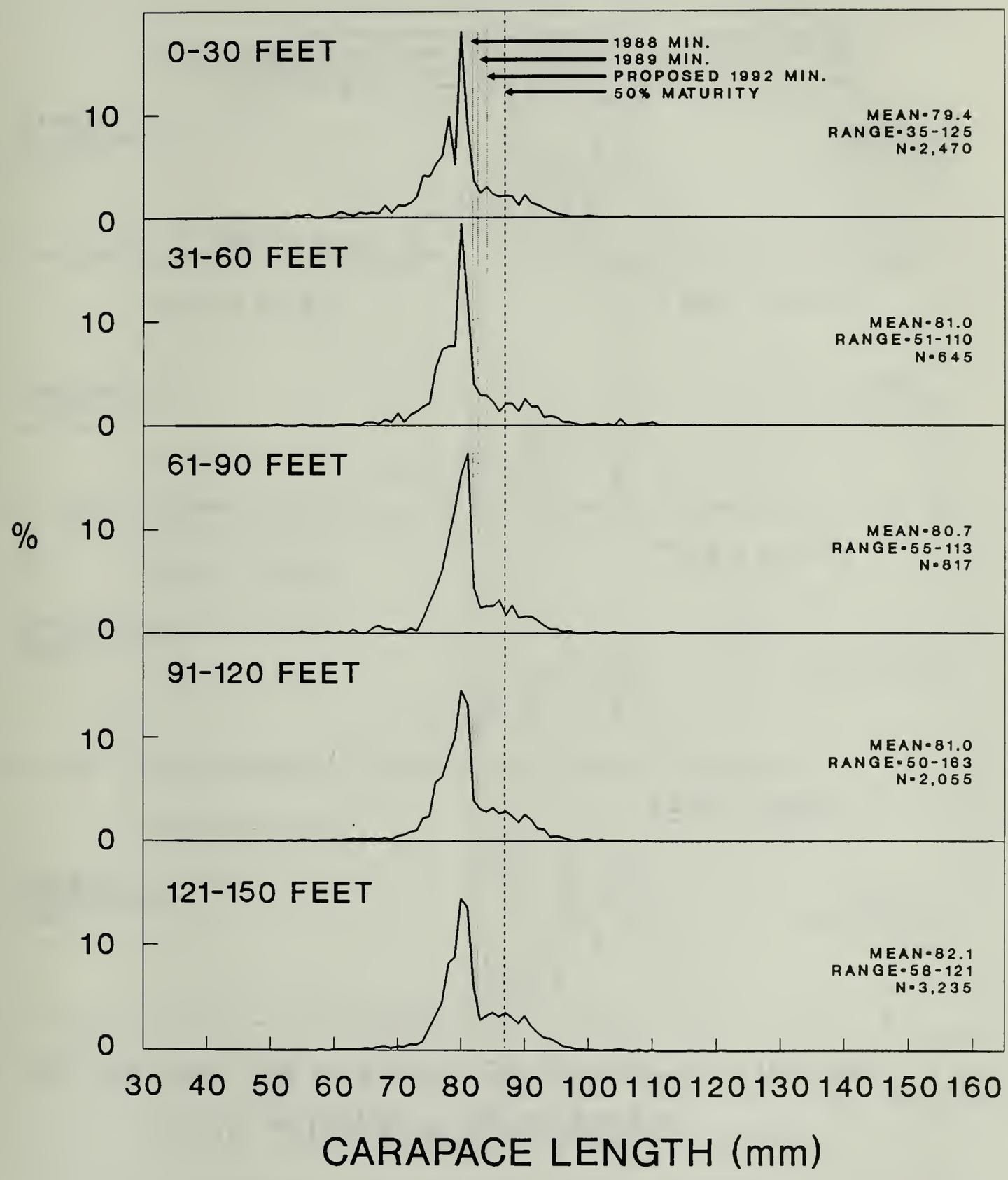

Figure 10. Carapace length frequency of all lobster, by 30 foot depth zones, from commercial lobster trap sampling in Cape Cod Bay region, Massachusetts, 1988.

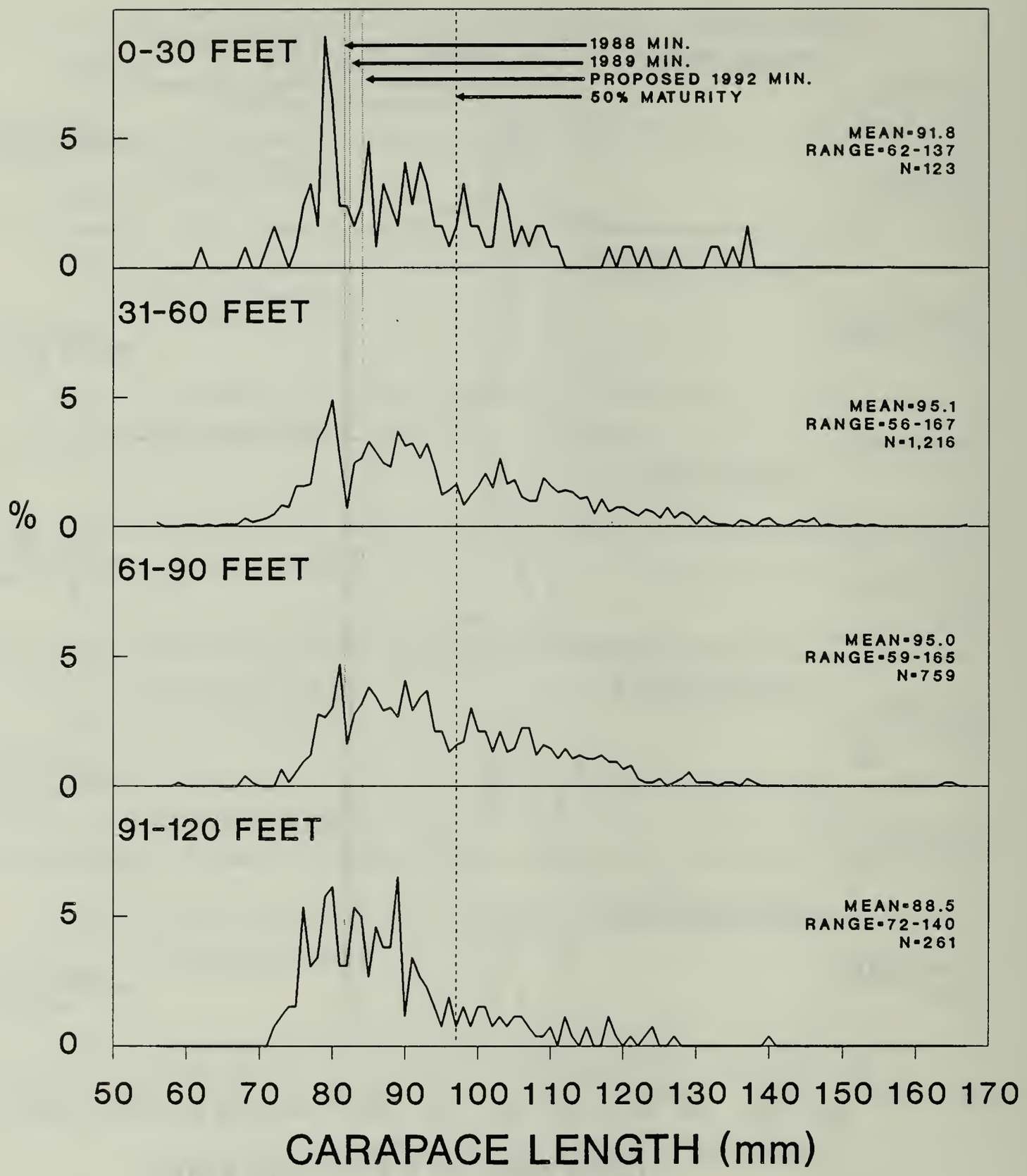

Figure 11. Carapace length frequency of all lobster, by 30 foot depth zones, from commercial lobster trap sampling in outer Cape Cod region, Massachusetts, 1988.

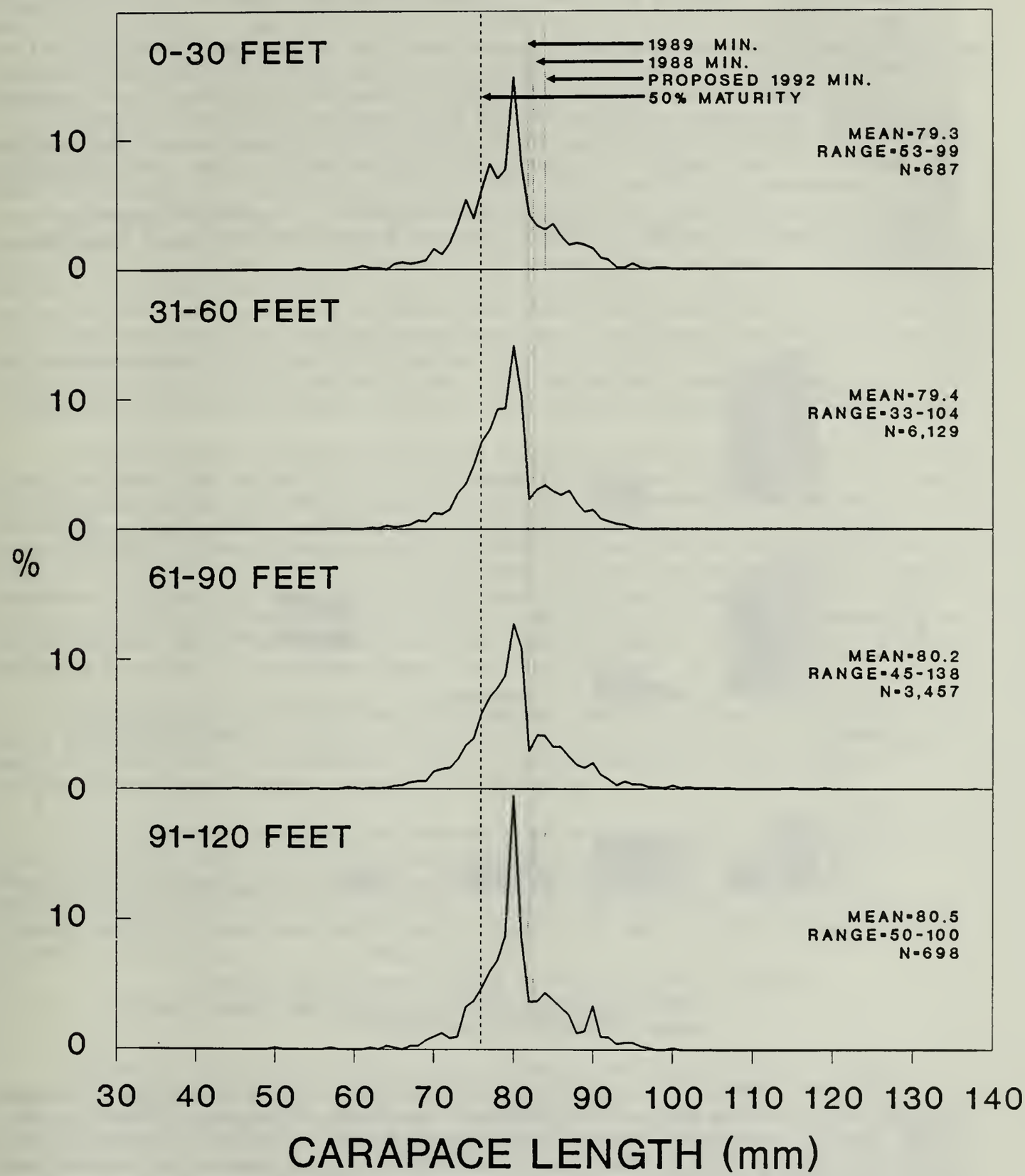

Figure 12. Carapace length frequency of all lobster, by 30 foot depth zones, from commercial lobster trap sampling in Buzzards Bay region, Massachusetts, 1988.

The upper limit of the size range in inshore commercial catches is determined more by fishing pressure than by migratory behavior. Historical accounts indicate that a large average size characterized the inshore lobster resource years ago. A comparison of recent and 30-year-old size frequency data revealed the effect of escalated fishing effort (Estrella and McKiernan In press). Length frequency data collected in July-September, 1957 by sea-sampling commercial traps from three coastal Massachusetts regions were compared to data which were similarly collected in 1986 during the same months and from the approximate locations (Figure 13). Size frequencies from Beverly-Salem, Cape Cod Bay, and outer Cape Cod regions were analyzed by 15% increments. A two year comparison of group frequencies with Chi-square test demonstrated that annual size frequencies were significantly different for each of these regions ($P<0.01$). This analysis by molt group clearly demonstrates that larger lobster comprised a greater percentage of the catch in 1957 than in 1986.

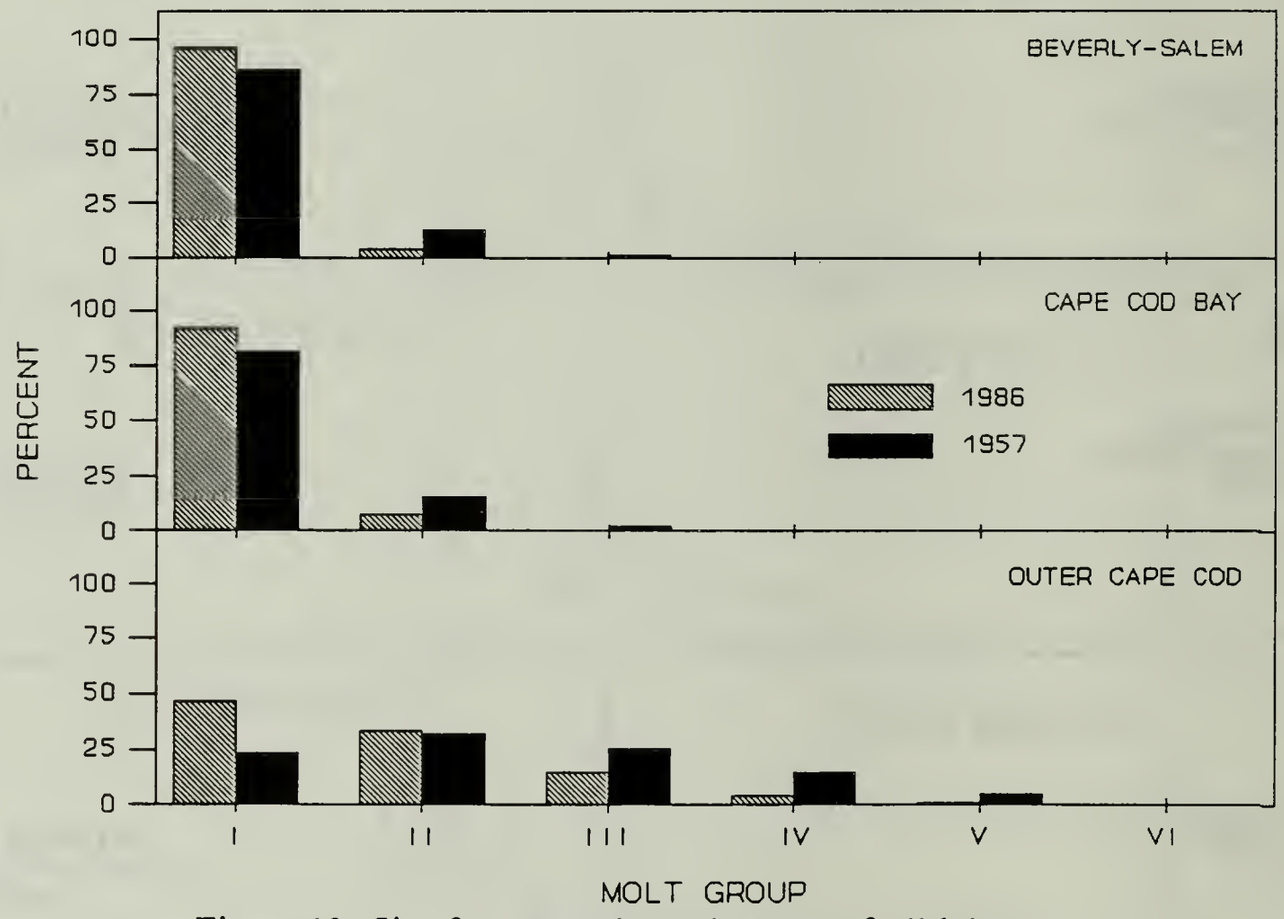

Figure 13. Size frequency by molt group of all lobster from commercial lobster trap sampling, Massachusetts coastal waters, 1957 and 1986.

The prevalence of larger lobster in 1957 is indicative of a lower level of fishing pressure than in recent years with 95,209 traps reportedly fished and 3,679,953 lbs. of lobster landed. In contrast, licensed lobstermen reported fishing 299,368 traps and landing 9,282,695 pounds in 1981 (landward of 69 degrees West Longitude and 41 degrees North Latitude). In 1986, 399,808 traps reportedly captured 12,580,793 pounds. The mean pounds/pot index declined from 39 in 1957 to 31 between 1981 and 1986. The pounds/pot/fishermen index also declined from 0.0227 in 1957 to 0.0215 in 1981 and 0.0208 in 1986.

Other historical accounts of the fishery indicate that larger lobster were more prevalent in inshore in years past. Even records from the early colonists note the presence of numerous large lobster in the intertidal zone!

A "bottleneck" hypothesis, which was originally proposed by Caddy (1986), has been used to argue against the gauge increase and the effectiveness of subsequent increases in fecundity. It states that the lobster resource is limited in size by the amount of habitat into which postlarval lobster are inclined to settle. It has been stated that inshore cobble habitat provides this "bottleneck", or limiting factor and that lobster which are not accommodated by this potentially saturated habitat are lost to predation.

Howard and Bennett (1979) and Pottle and Elner (1982) found that lobster tend to choose gravel rather than silt/clay substrates. However, when Botero and Atema (1982) included macroalgal-covered rock in the choice options, it was preferred by settling lobster. Barshaw and Bryant-Rich (1988) emphasized the importance of macroalgal-covered rock habitat and the faster settlement of post larval lobster into it compared to rock and mud, and a lower rate of lobster mortality experienced on it. Although mud habitat is the least preferred the demonstrated ability of lobster to burrow into it (MacKay 1926; Cobb 1971; Berrill and Stewart 1973; Botero and Atema 1982) implies that when mud habitat is the only option, juvenile lobster will settle into it and construct and maintain burrows there.

The importance of macroalgal-covered rock and other habitat types which greatly exceed the total area that inshore cobble represents (throughout the range of the lobster) has been underrated when considering a bottleneck hypothesis which isolates cobble as the key habitat. Undoubtedly, suitable cover, which is provided by natural structure, vegetation, and/or through burrowing, is essential to the survival of postlarval lobster. A perceived difference in density of juvenile lobster between inshore and offshore regions may raise the question of the availability of suitable habitat in deeper offshore water. However, significant juvenile lobster populations have been observed in various offshore canyon regions. (Skud 1969; Skud and Perkins 1969; Campbell et al. 1984). It is assumed that these juveniles did not migrate there from inshore areas.

Factors other than habitat may effect resource stability. The influence of variable size at age on recruitment should not be discounted. This would result in a year-class recruiting to the fishery over several years. A weaker year-class would thus be "overlapped" and supported by previous, stronger ones.

There have also been concerns expressed that the gauge increase program may eliminate the "chicken" market. The weight-length relationship developed for Massachusetts Lobster (Estrella 1986) indicates that the average weight of the new minimum sized lobster (84 mm C.L. or 3 5/16 " C.L.) will be 1.07 lbs. This represents a relatively small increase from the average weight of 0.95 lbs at the former minimum size (81 mm or 3 3/16" C.L.).

ACKNOWLEDGEMENTS

We are indebted to the many commercial lobstermen who are involved in this cooperative lobster resource monitoring effort. The success of this program is due primarily to their continued interest and cooperation. Unfortunately, we must refrain from naming them in order to protect the confidentiality of their catch information. Gratitude is also extended to Brian Kelly, Vincent Malkoski and Joe Battaglia of the Pilgrim Power Plant Project (funded by Boston Edison Company), Dan McKiernan, Peter Hoar, Thomas Hoopes and Brad Chase for data collection, Ann Spires for data entry, James Fair who administered the project and reviewed the manuscript, and Kim Trotto who supplied word processing assistance. Main frame data processing, including a portion of the data entry, was supported by the National Marine Fisheries Service (NMFS) Northeast Fisheries Center, Woods Hole, MA.

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APPENDIX

Table 1. CTH'3, by state and region, for all marketable lobster sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1981-1988.

	1981	1982	1983	1984	1985	1986	1987	1988
State	0.767	0.785	0.803	0.696	0.825	0.816	0.737	0.820
Cape Ann	0.732	0.808	0.624	0.663	0.634	0.699	0.669	0.496
Beverly-Salem	0.934	0.898	0.881	0.835	0.663	0.496	0.611	0.661
Boston Harbor	--	--	--	1.108	1.254	1.096	1.058	1.057
Cape Cod Bay	0.710	0.776	0.680	0.479	0.716	0.822	0.533	0.752
Outer Cape Cod	0.808	0.824	0.765	0.598	0.856	0.811	0.937	0.861
Buzzards Bay	0.611	0.571	1.110	0.870	0.953	0.907	0.952	1.064

Table 2. CTHSOO, by state and region, for all sub-legal American lobster, sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1981-1988.

	1981	1982	1983	1984	1985	1986	1987	1988
State	0.580	0.672	0.718	0.521	0.647	0.700	0.578	0.509
Cape Ann	0.067	0.109	0.586	0.450	0.395	0.474	0.417	0.388
Beverly-Salem	0.708	0.711	1.263	0.948	0.833	0.801	0.863	0.353
Boston Harbor	--	--	--	0.901	1.162	1.138	1.156	0.639
Cape Cod Bay	0.710	1.013	0.639	0.322	0.594	0.551	0.371	0.438
Outer Cape Cod	0.037	0.024	0.038	0.033	0.035	0.027	0.088	0.064
Buzzards Bay	0.787	0.620	0.638	0.785	0.848	1.312	0.871	1.153

Table 3. CTHAUL, by state and region, for all sub-legal American lobster, sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1981-1988.

	1981	1982	1983	1984	1985	1986	1987	1988
State	1.473	1.401	1.624	1.389	1.705	1.899	1.873	1.736
Cape Ann	0.256	0.199	1.044	0.909	1.031	1.126	1.143	1.062
Beverly-Salem	1.855	1.713	2.526	2.504	2.567	2.435	3.482	1.862
Boston Harbor	--	--	--	2.773	3.038	3.314	3.334	1.959
Cape Cod Bay	1.544	1.680	1.345	0.825	1.337	1.512	1.031	1.442
Outer Cape Cod	0.233	0.145	0.210	0.189	0.160	0.161	0.324	0.353
Buzzards Bay	2.381	1.916	2.316	1.965	2.452	3.118	3.090	3.722

Table 4. Percent of females ovigerous, by state and region, for all American lobster sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1981-1988.

	1981	1982	1983	1984	1985	1986	1987	1988
State	5.9	7.7	10.9	9.1	8.6	9.1	9.2	8.8
Cape Ann	1.7	3.1	4.4	3.2	4.6	5.0	4.5	3.5
Beverly-Salem	1.7	2.8	1.2	0.4	1.9	1.1	1.8	1.5
Boston Harbor	--	--	--	1.4	1.2	2.0	1.7	2.0
Cape Cod Bay	3.9	3.1	3.7	3.1	3.2	2.1	3.9	2.9
Outer Cape Cod	11.1	23.0	30.3	26.8	22.3	28.9	16.9	21.4
Buzzards Bay	16.0	16.9	32.5	26.6	25.0	25.3	31.0	27.8

Table 5. CTHSOD, by state and region, for all ovigerous female American lobster sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1981-1988.

	1981	1982	1983	1984	1985	1986	1987	1988
State	0.024	0.027	0.050	0.038	0.044	0.057	0.049	0.054
Cape Ann	0.002	0.011	0.024	0.015	0.016	0.017	0.016	0.010
Beverly-Salem	0.011	0.009	0.008	0.003	0.011	0.004	0.010	0.004
Boston Harbor	--	--	--	0.009	0.007	0.015	0.012	0.012
Cape Cod Bay	0.020	0.025	0.016	0.009	0.015	0.010	0.012	0.009
Outer Cape Cod	0.012	0.028	0.040	0.030	0.038	0.032	0.034	0.030
Buzzards Bay	0.079	0.053	0.230	0.183	0.193	0.297	0.234	0.289

Table 6. CTHAUL, by state and region, for all ovigerous female American lobster sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1981-1988.

	1981	1982	1983	1984	1985	1986	1987	1988
State	0.073	0.078	0.179	0.116	0.133	0.167	0.183	0.189
Cape Ann	0.010	0.016	0.038	0.027	0.039	0.047	0.048	0.031
Beverly-Salem	0.025	0.033	0.016	0.006	0.033	0.018	0.036	0.021
Boston Harbor	--	--	--	0.030	0.025	0.050	0.037	0.038
Cape Cod Bay	0.048	0.048	0.040	0.024	0.040	0.031	0.038	0.034
Outer Cape Cod	0.081	0.178	0.242	0.170	0.176	0.225	0.157	0.198
Buzzards Bay	0.243	0.139	0.828	0.515	0.555	0.748	0.889	0.929

Table 7. Estimated fishing pressure index, by state and region, commercial lobster trap catch survey, Massachusetts coastal waters, 1981-1988.

	1981	1982	1983	1984	1985	1986	1987	1988
State	86	87	86	86	88	88	89	90
Cape Ann	91	92	87	89	87	87	88	90
Beverly-Salem	89	92	94	88	96	96	97	98
Boston Harbor	--	--	--	93	94	96	96	96
Cape Cod Bay	90	93	92	94	93	94	92	94
Outer Cape Cod	46	43	42	38	48	46	54	57
Buzzards Bay	98	96	96	94	96	97	97	97

Table 8A. Total instantaneous (Z)* and total annual (A)** mortality estimates (Gulland 1969) of American lobster by state and region, Massachusetts coastal waters, 1981-1988.

	1981	1982	1983	1984	1985	1986	1987	1988
State	1.58*	1.72	1.66	1.66	1.76	1.80	1.90	1.86
	79%**	82%	81%	81%	83%	84%	85%	84%
Cape Ann	1.65	2.18	1.72	1.92	1.94	2.03	1.85	1.75
	81%	89%	82%	85%	86%	87%	84%	83%
Beverly-Salem	1.97	2.15	2.41	2.71	3.64	3.60	3.49	3.31
	86%	88%	91%	93%	97%	97%	97%	96%
Boston Harbor	--	--	--	2.52	3.59	2.60	2.77	2.86
	--	--	--	92%	97%	93%	94%	94%
Cape Cod Bay	2.53	2.69	2.42	2.52	2.31	2.83	2.26	2.74
	92%	93%	91%	92%	90%	94%	90%	94%
Outer Cape Cod	0.43	0.46	0.42	0.33	0.52	0.51	0.80	0.71
	35%	37%	34%	28%	41%	40%	55%	51%
Buzzards Bay	3.02	3.00	8.64	3.14	3.55	3.71	3.48	3.18
	95%	95%	99%	96%	97%	98%	97%	96%

Table 8B. Total instantaneous (Z)* and total annual (A)** mortality estimates (Beverton and Holt 1956) of American lobster by state and region, Massachusetts coastal waters, 1981-1988.

	1981	1982	1983	1984	1985	1986	1987	1988
State	1.35*	1.45	1.39	1.41	1.47	1.49	1.54	1.56
	74%**	77%	75%	76%	77%	78%	79%	79%
Cape Ann	1.32	1.39	1.35	1.52	1.33	1.32	1.39	1.51
	73%	75%	74%	78%	74%	73%	75%	78%
Beverly-Salem	1.59	1.70	1.85	1.78	1.96	1.99	2.16	1.98
	80%	82%	84%	83%	86%	86%	88%	86%
Boston Harbor	--	--	--	1.82	1.75	1.92	1.88	1.84
	--	--	--	84%	83%	85%	85%	84%
Cape Cod Bay	1.64	1.92	1.72	2.07	1.88	1.92	1.78	1.87
	81%	85%	82%	87%	85%	85%	83%	85%
Outer Cape Cod	0.54	0.55	0.53	0.52	0.57	0.55	0.66	0.66
	42%	42%	41%	41%	43%	42%	48%	48%
Buzzards Bay	2.97	2.53	2.26	2.21	2.36	2.41	2.36	2.35
	95%	92%	90%	89%	91%	91%	91%	94%

Table 9. Instantaneous fishing mortality estimates (F), by state and region, commercial lobster trap catch survey, Massachusetts coastal waters, 1981-1988.

	1981	1982	1983	1984	1985	1986	1987	1988
State	1.14	1.21	1.17	1.19	1.25	1.28	1.32	1.36
Cape Ann	1.33	1.47	1.11	1.33	1.28	1.22	1.30	1.37
Beverly-Salem	1.42	1.47	1.64	1.68	1.81	1.93	1.89	2.02
Boston Harbor	--	--	--	1.77	1.70	1.80	1.87	1.83
Cape Cod Bay	1.53	1.60	1.58	1.73	1.59	1.70	1.56	1.70
Outer Cape Cod	0.47	0.48	0.45	0.42	0.47	0.47	0.57	0.53
Buzzards Bay	2.32	2.13	1.94	1.80	2.04	2.11	2.08	2.06

Table 10. Estimated exploitation rate (u), by state and region, commercial lobster trap catch survey, coastal Massachusetts waters, 1981-1988.

	1981	1982	1983	1984	1985	1986	1987	1988
State	0.62	0.64	0.63	0.64	0.65	0.66	0.68	0.69
Cape Ann	0.74	0.80	0.61	0.68	0.71	0.67	0.70	0.71
Beverly-Salem	0.71	0.71	0.75	0.79	0.79	0.83	0.77	0.88
Boston Harbor	--	--	--	0.82	0.81	0.80	0.84	0.84
Cape Cod Bay	0.75	0.71	0.75	0.73	0.72	0.75	0.73	0.77
Outer Cape Cod	0.37	0.37	0.35	0.33	0.36	0.36	0.41	0.38
Buzzards Bay	0.74	0.78	0.77	0.72	0.79	0.80	0.80	0.82

Table 11. Mean carapace length (mm), by state and region, for all marketable American lobster sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1981-1988.

	1981	1982	1983	1984	1985	1986	1987	1988
State	88.5	87.9	88.1	88.2	87.8	87.6	87.5	88.2
Cape Ann	88.6	88.3	88.3	87.9	88.4	88.3	88.0	88.3
Beverly-Salem	87.6	87.0	86.6	86.9	86.2	86.2	85.8	87.1
Boston Harbor	--	--	--	86.8	86.9	86.4	86.6	87.5
Cape Cod Bay	87.2	86.4	86.9	86.1	86.4	86.3	86.7	87.3
Outer Cape Cod	98.2	97.5	97.4	99.7	97.0	96.3	94.6	95.2
Buzzards Bay	84.7	85.2	85.7	85.8	85.2	85.3	85.3	86.1

Table 12. Mean carapace length (mm), by state and region for all sub-legal American lobster, sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1981-1988.

	1981	1982	1983	1984	1985	1986	1987	1988
State	75.8	76.3	76.2	76.1	76.3	76.1	76.1	76.3
Cape Ann	78.0	77.7	77.5	77.3	77.6	77.1	75.9	77.0
Beverly-Salem	74.3	76.5	74.9	76.1	75.9	74.7	74.7	74.5
Boston Harbor	--	--	--	77.1	76.9	76.9	76.5	75.6
Cape Cod Bay	76.6	76.4	76.7	75.6	76.1	76.2	75.6	76.9
Outer Cape Cod	75.9	76.2	77.1	75.1	76.6	75.9	77.0	77.1
Buzzards Bay	75.8	75.5	76.8	76.4	76.1	76.0	76.6	76.3

Table 13. Mean carapace length (mm) of all ovigerous female American lobster, by state and region, sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1981-1988.

	1981	1982	1983	1984	1985	1986	1987	1988
State	88.5	87.6	88.6	87.4	87.9	88.1	87.1	87.2
Cape Ann	109.0	100.3	94.3	90.5	93.8	95.0	91.6	94.0
Beverly-Salem	80.5	84.5	85.8	83.5	85.9	83.5	81.8	83.0
Boston Harbor	--	--	--	82.1	84.0	81.3	82.3	83.7
Cape Cod Bay	86.4	83.8	85.5	84.4	85.2	86.8	87.0	84.7
Outer Cape Cod	109.8	106.1	108.0	107.1	106.9	107.3	102.5	105.2
Buzzards Bay	78.1	79.6	81.6	83.0	80.1	79.4	80.2	80.6

Table 14. Cull rate (percent), by state and region, for all American lobster sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1981-1988.

	1981	1982	1983	1984	1985	1986	1987	1988
State	10.0	10.8	10.7	14.8	18.1	20.9	17.0	18.2
Cape Ann	10.0	9.8	10.5	11.5	23.9	25.3	20.2	21.2
Beverly-Salem	8.3	8.6	10.2	20.9	23.0	30.0	24.1	26.3
Boston Harbor	--	--	--	13.3	19.3	19.1	16.9	16.3
Cape Cod Bay	11.1	10.7	10.9	15.6	18.3	21.6	16.2	17.4
Outer Cape Cod	5.7	11.3	8.9	13.0	13.4	16.1	12.6	15.0
Buzzards Bay	13.5	14.7	12.4	12.4	13.4	14.6	15.1	15.6

Table 15. Cull rate (percent), by state and region, for all legal American lobster, sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1981-1988.

	1981	1982	1983	1984	1985	1986	1987	1988
State	8.1	9.7	9.2	12.7	14.8	17.0	14.7	15.7
Cape Ann	10.7	9.6	7.5	10.4	19.4	20.3	18.0	19.3
Beverly-Salem	4.3	7.7	7.4	15.5	19.3	22.1	17.1	21.4
Boston Harbor	--	--	--	10.1	16.2	15.8	12.9	13.1
Cape Cod Bay	9.3	9.3	10.0	13.2	14.5	18.1	15.0	15.6
Outer Cape Cod	5.3	10.3	8.1	13.3	12.5	14.9	13.1	14.3
Buzzards Bay	16.1	13.2	12.7	12.3	13.8	13.6	15.2	14.1

Table 16. Cull rate (percent), by state and region, for marketable American lobster sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1981-1988.

	1981	1982	1983	1984	1985	1986	1987	1988
State	8.2	9.9	9.2	13.2	16.2	17.6	14.7	16.0
Cape Ann	10.8	9.8	7.3	10.5	20.9	20.7	18.4	19.9
Beverly-Salem	4.4	8.0	7.4	15.6	18.5	22.2	17.2	21.3
Boston Harbor	--	--	--	10.2	16.2	15.7	12.8	13.1
Cape Cod Bay	9.3	9.3	10.0	13.2	15.9	18.2	14.8	15.6
Outer Cape Cod	5.3	10.9	8.6	14.8	12.9	16.8	13.2	14.9
Buzzards Bay	16.9	13.1	12.3	12.6	15.4	14.1	15.4	14.7

Table 17. Cull rate (percent), by state and region, for sub-legal American lobster, sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1981-1988.

	1981	1982	1983	1984	1985	1986	1987	1988
State	11.2	11.5	11.6	16.1	20.2	23.2	18.2	19.6
Cape Ann	8.0	10.6	12.6	12.2	26.9	28.7	21.5	22.1
Beverly-Salem	10.0	9.0	11.2	22.3	24.0	31.8	25.3	28.6
Boston Harbor	--	--	--	14.5	20.5	20.0	18.0	18.0
Cape Cod Bay	11.9	11.3	11.4	17.0	20.2	23.4	16.8	18.3
Outer Cape Cod	7.8	17.9	13.5	11.7	18.6	22.8	11.0	16.9
Buzzards Bay	12.7	15.2	12.2	12.4	13.3	14.9	15.0	16.2

Table 18. Percent trap mortality by state and region for all American lobster sampled during commercial lobster trap catch survey, Massachusetts coastal waters, 1981-1988.

	1981	1982	1983	1984	1985	1986	1987	1988
State	0.15	0.04	0.22	0.15	0.18	0.20	0.10	0.15
Cape Ann	0.00	0.00	0.09	0.27	0.03	0.16	0.00	0.03
Beverly-Salem	0.00	0.00	0.00	0.00	0.04	0.22	0.03	0.19
Boston Harbor	--	--	--	0.00	0.03	0.03	0.23	0.09
Cape Cod Bay	0.00	0.02	0.03	0.00	0.00	0.02	0.15	0.00
Outer Cape Cod	0.46	0.22	0.23	0.48	0.40	0.85	0.27	0.66
Buzzards Bay	0.62	0.00	1.13	0.43	0.76	0.25	0.01	0.18